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ABSTRACT

Experiments conducted between 1968 and 1973 studied the various ways that colleges might provide instructional computer access for students at reasonable cost. Ten colleges, representing a variety of computer needs and a diversity of preference in choice of computer vendor, configuration, and mode of operation, participated in an experiment to find if new "minicomputers" might be able to provide instructional computing support that even the smallest colleges could afford. A basic conclusion, expressed unanimously by the ten somewhat varied undergraduate institutions, is that a minicomputer system is the best-buy source of computing power for most instructional activities. The combination of low cost, constant availability control, and the many advantages of an on-campus facility make the minicomputer a preferred choice over known off-campus alternatives. (Author/KE)

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USE OF MINICOMPUTER FACILITIES FOR HIGHER EDUCATION INSTRUCTION

National Science Foundation Grants
1072, 1111, 1116-22, 1139-40

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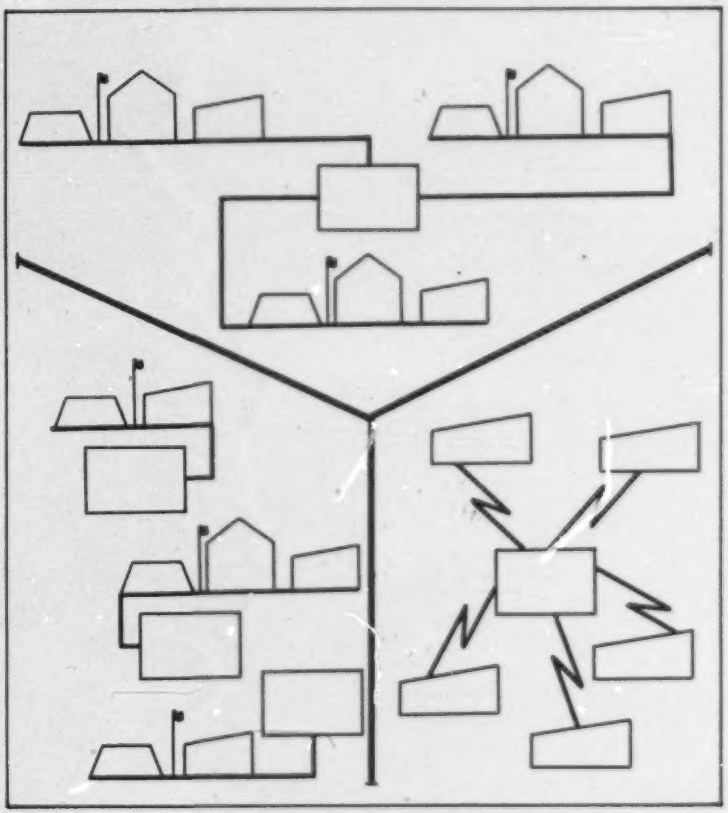

HE 006 763

Use of Minicomputer Facilities for Higher Education Instruction

Vincent H. Swoyer
January, 1975

Summary report on an experiment to study the value of minicomputers used to supply instructional computing on ten college campuses, supported by NSF Grants 1072, 1111, 1116-22, 1139-40.

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Introduction

Background

This is a report on the third of a series of experiments funded by the National Science Foundation directed at the evaluation of alternative sources of computing to serve instructional needs in higher education. These experiments, conducted between 1968 and 1973, studied the various ways that colleges might provide instructional computer access for students at reasonable cost. Among considerations evaluated during the initial two series, three alternatives appeared promising:[1]

1. *Use of remote terminals connected to a university or commercial time-sharing computer facility.* One or two typewriter terminals per campus were connected to a variety of computers in an interactive or remote job entry mode. The average cost per college was about $16,000 per year, or $19 per registered student. Following the experiment, some institutions felt that the level of computing afforded an entire campus by one or two terminals was insufficient to justify the cost. In many cases the terminal service was discontinued after the supporting grant expired.

2. *Sharing the use of a small computer among several institutions.* This was evaluated by five institutions in the same locality sharing the use of a common IBM 1130 for instructional use. The group of colleges spent about $70,000, or $13 per registered student. The main disadvantage to this system was the inconvenience to students who had to travel or transport input and output in order to make use of the facility.

3. *Use of an independent small computer in each college.* Six colleges in this experiment each installed IBM 1130 computers, with the ability to perform some administrative computing, a partial justification of the computer's cost. The average annual cost was about $57,000, or $36 per registered student. The fraction of the cost prorated to educational use averaged $33,000 per year, or $21 per registered student. The principal disadvantage of this source of academic computing was the possible growth of administrative computing demands conflicting with increased academic needs.

Although each of the methods offered a level of computing suitable for some instructional use, a belief was expressed in 1969 that the new "minicomputers" might be able to provide instructional computing support that even the smallest colleges could afford. An experiment was funded by NSF in August, 1970, which assisted ten colleges' acquisition of minicomputers with coordinating supervision by SREB.

[1]Hamblen, John W. and Bruce K. Alcorn, *Computer Facilities for Instruction in Small Colleges: Final Report Summary 1968-71.* Atlanta: Southern Regional Education Board, Computer Sciences Project, 1972.

The Experiment

The ten colleges in the experiment exhibited a variety of computing needs and a diversity of preference in choice of computer vendor, configuration, and mode of operation. At the time of the start of the experiment, circa 1969, the purchase of a minicomputer by a small college posed an element of risk few felt they could afford. There was almost no experience base on which to rate the expected performance of a minicomputer in an educational environment, and, although many faculty had previous experience in the use of computers, almost none were well versed in the elements of systems selection, software, hardware, or operational considerations. The grants from NSF were intended to partially offset the risk, and the introduction of the SREB office of the Computer Science Project, plus support for a series of follow-on consultant visits, assisted with the establishment of reasonable initial computer operations on each campus. The experiment required institutional commitment to provide information about progress and use of the facilities through the three-year project period. A number of joint meetings of the institutional principal investigators were scheduled at regular intervals, and several series of on-site campus visits were conducted by Dr. John Hamblen of SREB, who was the project director, and Dr. Vincent Swoyer of the University of Rochester, who was consultant to the project.

Reports on the Findings of the Experiments

Each participating college prepared annual reports on prescribed items relating to hardware characteristics, software, services, costs, usage, academic developments, significant successes, problem areas, special developments, and noteworthy cooperative activities. A report compending the details of the individual college annual reports was prepared by Dr. Hamblen and submitted to NSF in early 1974 following the end of the three-year experiment period.[2]

This report is a summary of the experiences of the ten colleges, based on the annual reports of the colleges, as well as interviews and conversations with each college's principal investigators, faculty, administration, and students obtained during joint meetings and a series of campus visits throughout the experiment. It is hoped that this report will be of assistance and interest to small colleges which are contemplating or have installed minicomputers to serve instructional needs. Large institutions may also find interest in this report, since it is now evident that minicomputer systems have real value in support of instructional programs at many of our largest universities.

[2]Hamblen, John W., *Mini and Very Small Computer Facilities for Instruction in Small Colleges: Final Detail Report 1970-73*. Atlanta: Southern Regional Education Board, Computer Sciences Project, 1974.

Section II

Spring, 1970: The Colleges, and the Status of Academic Computing

The initial situation at the ten experimental colleges prior to the arrival of instructional minicomputers provides a "before" picture of each campus. The following describes the pre-experiment status of computing at each institution and provides some background information about the college. Institutions are listed alphabetically.

Benedict College: Columbia, South Carolina.

Benedict College is a private college with an enrollment of about 1300 students. The institution is coeducational, with a traditionally black student population. During the late 1960's Benedict began a number of new academic programs aimed at technological areas, including computer science, physics, and educational television. Computing prior to 1970 was obtained by purchasing batch computer time from an IBM 7040 facility at the University of South Carolina and on an IBM 360/25 at Consultronics Institute. The college leased two IBM 026 keypunches and estimated its annual budget for computing to be approximately $6,500. Faculty experience with computers was limited, involving only three or four younger faculty who were users of computing facilities at other institutions during doctoral studies. A two course sequence in FORTRAN and COBOL programming, offered through the mathematics department, represented the extent of computer-related instruction. The disadvantages of transporting input decks and output listings to and from remote sites made the low-cost minicomputer an attractive alternative in 1970.

Canisius College: Buffalo, New York.

Canisius is a private, Catholic church affiliated, coeducational institution. With 3,500 students, this was the largest college in the experiment. An administrative data processing facility, based on a Honeywell 200, operated on campus beginning in 1968. Two full credit Computer Science courses and three other courses containing significant computing segments were offered in 1970, although there was no academic computer. Some use was made of a CDC 6400 computer at the University of Buffalo, but the combination of inconvenience and relatively high costs made this arrangement unfavorable for instructional computing. Nevertheless, the ongoing computing instruction in 1970 involved over 100 students per term in full course offerings, with a promise of growth if more convenient academic computing facilities were to be available.

Delaware State College: Dover, Delaware.

Delaware State College is a state supported undergraduate institution of about 1000 predominantly black (60%) students. An IBM 1130 computer was installed in 1963 to provide facilities for administrative and academic computing. After many years of operation, the IBM 1130 became heavily committed to administrative requirements. A further instructional disadvantage was a general inability for students to access the few keypunches to prepare input. A computing course had been offered by the mathematics department, beginning in 1966, but interest was only 10 to 15 students per year. The light interest in this kind of course was attributed partly to the general unavailability of the IBM 1130 for academic work. There was a desire at Delaware State to offer computer courses of general interest (the existing course had a calculus course prerequisite) which could be serviced by a computer facility easily available for academic use.

Erskine College: Due West, South Carolina.

Erskine College is a private coeducational undergraduate institution with an enrollment of about 700 students. No computing equipment of any kind had ever been installed on campus. The only computing course offered before Erskine's participation in the experiment was a Saturday only schedule for COBOL instruction, using an IBM 360/30 belonging to a neighboring textile company. To the college's potential advantage, however, was a faculty containing a high fraction of recent Ph.D.'s. Seven of 49 full-time faculty had computing experience at major university installations. Erskine represented the only institution in the experiment which had no history of computing equipment, terminal access to a computer, or batch access arrangements with an academic computing facility.

Hollins College: Roanoke, Virginia.

Hollins College is an independent liberal arts college for women, offering undergraduate degrees in 28 areas and Masters of Arts in psychology and creative writing, and in liberal studies. The enrollment is about 1000 undergraduate and about 150 graduate students. Prior to the experiment, general academic computing barely existed, with only a single teletype tied to a commercial time-sharing service in Raleigh, N.C. daily during the off-hours from 7 p.m. to 7 a.m. Some research was conducted using a major computing facility at VPI, but this was 40 miles distant. There was a four-year history of some computer use for on-line instrumentation control during which the psychology department had installed a

PDP-8 for use with experiments on stuttering and other on-line projects. Faculty experience with computers reflected the expected degree of expertise with laboratory applications in psychology, mixed with a generally sparse number of other faculty having any computing background whatever. An annual computing budget of about $6,800 supported the student and faculty activities in computation. No full-term course in computing was offered, although an introduction to computing was serviced during the "short term" (the month of January) in 1968 and 1969 using the VPI system, and in 1970 using the off-hours time-shared terminal.

Illinois Benedictine College: Lisle, Illinois.

Illinois Benedictine College, which had been named St. Procopius College at the inception of the experiment, is a private, Catholic, coeducational institution with about 1000 undergraduate students. The college experienced a history of valid scientific computer requirements to support strong academic programs in physics and mathematics, but had an insufficient number of students to justify investment in a campus system. As early as 1962 arrangements to use computers at Argonne National Laboratories were commonplace at the college. As interest grew, transportation inconveniences and unpredictable turn-around times caused frustrations. By the spring semester of 1970, the college was spending $3,600 per four-month term to purchase one teletype's time-sharing service from a neighboring educational institition. A single terminal was not enough to satisfy the growing demand, however. The concept of an on-campus minicomputer system with 24-hour a day availability and control appeared as an outstanding match of low cost and increased capability.

MacMurray College: Jacksonville, Illinois.

MacMurray College is a private, coeducational institution with about 1000 undergraduate students. Prior to 1970 computer availability was represented by a single teletype terminal connected to a remote GE-255 computer. This time-sharing service was well received by the students, with the sign-up book 100% saturated. A substantial fraction of faculty had extensive computing experience, in the departments of chemistry, physics, mathematics, economics, and psychology. Batch computer arrangements via U.S. mail had been employed at times using computers at two universities and Argonne labs. A particular difficulty with this mode, however, was the need to arrange keypunching as well as computing service. MacMurray projected extensive plans to expand interactive use of computing by employing a half dozen interactive terminals to their own minicomputer during the experiment.

Maryville College: Maryville, Tennessee.

Maryville College is a private, undergraduate, liberal arts college of about 700 students. The college had participated, during 1968-70, in an NSF supported experiment which placed a single teletype terminal on campus connected to a commercial time-sharing service. Maryville had been noted to have virtually no computer experience prior to 1968. By 1970, the single terminal had facilitated the offering of an introductory computing course during each of the three academic terms. This course was limited to 15 students per term due to the constraint of a single teletype. Of special experimental interest at Maryville was the potential to compare single terminal access to a time sharing service, which had cost $11,000 per year, to the level of computer service obtainable from a more economical minicomputer with a $20,000 purchase price.

Mt. Union College: Alliance, Ohio.

Mt. Union College is a private, undergraduate institution of about 1200 students. By 1970, a computing facility consisting of a second-hand early IBM 1620 computer had been used for instruction, research, and some administrative use for four years. Of all colleges in the experiment, only Mt. Union had an academic computer operation prior to the arrival of the minicomputer. It was well organized with part-time direction from the physics department chairman, a half-time manager, and a half-time assistant director. There were no credit computing courses taught, although there was a desire to offer some if the necessary expansion in instructional computing facilities could be accomplished. The college had been investigating alternative computing methods for more than a year in an effort to offer what it defined as its principal instructional need: a system to process a substantial work flow of student FORTRAN programs. A batch-oriented minicomputer seemed to hold promise as a solution to this need.

University of the South: Sewanee, Tennessee.

The University of the South is an Episcopal institution which in 1970 had just changed from an all-male to a coeducational institution, and had plans to increase from 900 to about 1200 students over a three-year period. A flurry of computing activity had occurred in 1963, when the University purchased a minimal paper-tape IBM 1620 computer with a private donation. The faculty thrust of the computer effort was provided by a member of the Physics Department who planned a series of upgrade improvements to the 1620 through additional private donations he was soliciting. His untimely death curtailed these plans, and the computer was nearly

idle until 1968 when some use was made of the 1620 through the efforts of a new faculty member. The awkwardness of paper tape input and slow typewriter output rendered the existing computer ineffective as an instructional tool. In 1970 a nucleus of four faculty in various disciplines planned a combination of computer-oriented courses in mathematics, psychology, biology, and chemistry to be based on a minicomputer. These faculty had a breadth of computer experience as experimentalist users, through participating in computer-oriented calculus teaching workshops and during their own doctoral research projects.

Section III

Minicomputers Selected, Intended Languages and Modes of Operation

The equipment selection process, and associated plans for operation, occurred in a tentative form in February, 1970. In many cases, revisions to original plans continued right up to a month or so prior to delivery in the fall of 1970. For most institutions, this was the first experience ordering a computer. The early 1970 time frame deserves some reflection. Most major minicomputer vendors were in the process of releasing new lines of equipment which are now considered commonplace. Data General had barely entered the market with its first Nova. Digital Equipment Corporation had just delivered the first of its PDP-11 series. Hewlett-Packard was just beginning to extend the popular HP2000 series computers. It was a time when much of the minicomputer equipment was new even to the sales representatives. To the uninitiated consumer, there was, genuine cause for bewilderment. Several colleges planned a system in March of 1970, and by the time of the experiment's start in August discovered new equipment had come onto the market with greater appeal. The case for Data General equipment, for example, found some attractively priced new minicomputers available which were completely unknown when the initial systems were evaluated five months earlier.

Two types of incidents related to the newness of the systems available affected the overall hardware and software performance evaluations during the experiment. It was commonplace for a sales representative to announce the pending availability of a new operating system or compiler, which was required to fulfill a college's plans. Software was commonly delivered late, and in a large number of cases would not operate on the purchased computer because of an inadequacy such as too little memory. (To their credit, the vendors generally made generous adjustments to compensate for their earlier misleading announcements.) Another aggravation was the pattern of hardware malfunctions in some of the near prototype early model deliveries.

As an experiment, it was desirable to evaluate a variety of vendors, configurations, and modes of operation. The ten colleges exhibited many differences in these regards. Five of the institutions shifted vendors between the original proposal and equipment delivery time, with a final distribution of vendors reflecting four computers manufactured by Digital Equipment Corporation, four by the Hewlett-Packard Company, and two by the Data General Corporation. The following describes the computers selected, the initial modes of operation, and languages supported.

Benedict College: This college, as many in the experiment, compared the computer offerings of the three principal vendors (Digital Equipment, Data General, and Hewlett-Packard) plus several others. Although originally opting for another vendor's system, a decision was reached to acquire a moderate size time-shared PDP-8/I-D. The supporting reasons for this selection boiled down to a desire to obtain a proven system, with an ample library of programs, and an extensive array of software systems, developed both in house by the vendor and a large user community. The scant experience level of the college faculty and the absence of a large number of computer science sources precluded venture into the newer 16-bit minicomputers, most with announced but not-yet-delivered software. Benedict declared an early interest in an interactive approach to instructional computing, and tailored their system to offer good support to four interactive terminals, with an ability to expand to as many as 16 terminals. The operating system selected was the standard TSS/8 time-shared software set supported with a 262,000 word disk unit. The principal language to be supported was BASIC, although the availability of other languages was cited as an advantage. The system included 12,000 12-bit words of core memory, four ASR-33 hard-wired teletype terminals, and a high speed paper tape reader.

Canisius College: The environment at Canisius reflected more computer experience than most of the institutions. The minicomputer had a defined role, supplementing the existing college computer center's Honeywell 200 which was largely dedicated to administrative computing. The minicomputer system was to provide multiple-terminal time-sharing for the majority of students using a simple interactive language such as BASIC. A secondary desire was an ability to interface other laboratory equipment for on-line control or data acquisition. Canisius chose a Data General Supernova as their minicomputer. This computer was newly announced in mid-1970, and Canisius received one of the first models produced. The basic appeal of the Supernova was its high performance specifications at reasonable cost. The initial configuration of Supernova included 12,000 16-bit words core memory, a 256,000 word disk drive, three ASR-33 teletype terminals, and a Sykes magnetic tape cassette drive. It was oriented to the early Data General time-sharing system utilizing BASIC.

Delaware State College: Prior familiarity with a laboratory PDP-8 led to the selection of a PDP-8/I at Delaware State. Unlike Benedict and Canisius, the Delaware State facility was intended to operate as economically as possible in a batch mode, using an optical card reader for input cards which were hand marked. (This environment was appealing to a number of institutions because it represented the lowest total cost system, since there was no requirement for either card punches or a multiplicity of interactive termi-

nals to service a large number of educational users.) The Delaware State configuration represented one of the smallest systems, with 4,000 words of 12-bit word core memory, a 32,000 word disk drive, an optical mark card reader, and an ASR-33 teletype, used here as a control console. The system was oriented to process batch BASIC.

Erskine College: The objective of this institution was to support the general educational program with shared computer power accessed from at least three different campus locations. The distributed nature of input stations indicated the use of an interactive time-shared system, for which Erskine selected the newly-marketed PDP 11/20. Factors leading to the selection of the PDP-11 included (a) desire for a 16-bit rather than a 12-bit processor, (b) preference for a new computer that would have a longer life before obsolescence, and (c) a judgment that the PDP-11 would become popular and that extensive software would be available. The configuration included 16,000 words of 16-bit core memory, a 256,000 word disk drive, four ASR-33 teletype terminals, and a high-speed paper tape reader/punch. The computer was acquired with the intent to operate under the RSTS-11 time-sharing system due for release in early 1971. BASIC was intended as the language for almost all use.

Hollins College: Hollins' intention was to introduce a computing facility which would serve three functions: (1) Provide support for instruction in courses offered in mathematics, statistics, physics, social sciences, and other non-computer-science areas. (2) Provide a suitable system to serve as a base for a sequence of "computer science" type courses sufficient to serve as a minor or possibly an undergraduate major in computer science. (3) To interface on-line to laboratory equipment located in the science building.

In-house expertise on a PDP-8 used to control a psychology laboratory influenced the selection of similar equipment for the general purpose minicomputer. The intended principal of operation was interactive, using BASIC under TSS-8, with a desire for some batch FORTRAN capability. The computer selected was a PDP-8/I-D, similar to and somewhat larger than the Benedict College minicomputer. Included in the initial configuration were 12,000 12-bit words of core memory, a 256,000 word disk file, six ASR-33 teletype terminals, a high-speed paper tape reader, and some laboratory interface devices.

Illinois Benedictine College: Considerable study was given to computer selection by this college. Six different systems by five vendors were evaluated with considerations weighing budget vs. use compromises. A decision was reached to become principally batch oriented using an optical card reader, but with some time-sharing capability. After some deliberation, the college opted to use a disk-based operating system on a Hewlett-Packard HP2114. The minicomputer selected included 8,000 16-bit words memory (the maximum available on an HP2114), a 1,600,000 work disk file, two

ASR-35 teletype terminals, an opitcal card reader, and a high-speed paper tape reader. It was planned to support BASIC in either batch or interactive mode under the HP DOS operating system.

MacMurray College: From the start, MacMurray was oriented toward a campus-wide interactive computer system with dispersed terminals. Equipment selection was narrowed to two proven systems, the DEC PDP-8 and Hewlett-Packard 2116. The system selected was the HP2116, because it represented a proven system with 16-bit word length, compared to 12-bits on the PDP-8. Included in the initial HP2116 configuration were 16,000 16-bit words memory, a 492,000 word drum, and eight ASR-33 teletype terminals. The MacMurray minicomputer represented the largest interactive system in the experiment with a cost of about $91,000. It was planned for time-shared BASIC service.

Maryville College: Maryville was interested in supporting essentially the same kind of computer service as obtained from a commercial time-sharing service in 1969-70. Basically, this provided computer time for a course in programming, plus computing for courses in physics, science, psychology, chemistry, mathematics, and economics. Their objective was to offer as good or better service for less than the $15,000 annual cost of the time-shared system. The minicomputer selected was a batch oriented Hewlett-Packard 2114, with 8,000 16-bit words of memory, an ASR-33 teletype terminal/console, an optical mark card reader, and a high-speed paper tape reader. This happened to be the lowest priced initial system in the experiment, with a cost of $19,900. Although primarily a batch BASIC system, it was hoped that FORTRAN could also be supported for instructional use.

Mt. Union College: The plan of this installation was to provide a batch facility with the ability to rapidly process small programs written in FORTRAN IV. To accomplish this, the system was configured to be used with a line printer. In many respects the final system had capabilities similar to fairly large academic computers. The minicomputer selected by Mt. Union was a Hewlett-Packard 2116 with 16,000 16-bit words memory, a 1,240,000 word disk drive, an ASR-33 teletype (used as a control console), an optical card reader, and a high-speed paper tape reader. Although not delivered initially, a planned 300 lines-per-minute line printer was added during the first year. Languages to be supported were FORTRAN and BASIC, with a batch mode of operation. The Mt. Union minicomputer represented the highest priced batch system, costing about $93,000 for the initial configuration.

University of the South: The University of the South opted for a single-user (batch) system to provide BASIC and FORTRAN at minimum cost. Study of the available minicomputers in the spring of 1970 resulted in the selection of an 8,000 word computer with optical mark card reader. During the summer the Data General sys-

tems became better known, and the university shifted its preference to a similar Nova which presented somewhat better price-performance credentials. The initial minicomputer, then, was a Data General Nova, with 8,000 16-bit words of memory, an optical mark card reader, an ASR-33 teletype terminal and a high-speed paper tape reader. The intended mode of operation was batch, or a single user terminal, to support BASIC and FORTRAN.

Some General Observations about Equipment Selection:

Although the ten colleges varied somewhat in the objectives to be satisfied by the minicomputer system, some initial generalizations were apparent.

1. Institutions primarily interested in economical use by fairly large numbers of students opted for a batch mode of operation.
2. Three "least costly" systems, all batch or single-user oriented, were priced around $20,000 for a complete system. No single vendor was at the low-cost end of the scale, with a Data General Nova, a Digital Equipment PDP-8, and a Hewlett-Packard 2114 with very similar lowest price honors.
3. Irrespective of vendor, most instititions opted for a high-speed paper tape reader or reader/punch.
4. Five institutions chose to operate multiple terminals in a time-shared mode. Of these, all had at least 12,000 words of memory.
5. The common characteristic separating the "low-cost" $20,000 systems from the others (ranging upward from $40,000) was the exclusion or inclusion of a high-speed rotating secondary memory device (either a disk drive or a drum).
6. All time-shared systems had a disk or a drum.
7. The two "highest-priced" systems ($91-93,000) were both manufactured by Hewlett-Packard. One was batch oriented and the other was time-shared.
8. Although equipment from General Electric, Wang Laboratories, Xerox and Honeywell was included in the evaluating, the "big three" minicomputer vendors (DEC, Data General, and Hewlett-Packard) ended up as the only manufacturers represented.
9. Every installation planned to use BASIC, nine as the primary language. About half felt that some FORTRAN was important.

Section IV

Initial Installation; First Experience with Minicomputers

This section, and the next, deal with information relating how the colleges went about making use of their minicomputers, their experiences (both good and bad), and some of the lessons learned. Much of this information was collected during open discussions with experiment participants. It must be appreciated that the experiences described do not reflect a broad study of equipment or software performance. The experiences relate only to this experiment and, as noted earlier, at a time when equipment offerings and software developments were often brand new or under development. The Data General computers, for example, were early production models in their first year of manufacture. Conclusions drawn relate to the particular systems used and may not reflect the characteristics of later systems.

Space: A concern of an institution about to install a minicomputer is the place to put it. All colleges in the experiment were able to provide space, generally suitable and occasionally spacious. The type of installation fell into three broad classes, each with different space requirements.

1. *"Small" batch or single user systems.* These required, in addition to space to house the minicomputer itself, an area in which the users could perform certain tasks related to preparing input. Four of the institutions were in this class. On the average, a room of about 400 square feet was provided, although a room as small as 200 square feet could be considered passable. One institution housed the minicomputer system at the rear of a classroom, in a designated area of about 150 square feet. Naturally the classroom itself frequently doubled as the necessary work area. Although this worked out satisfactorily with respect to space, it constrained the scheduling of both the classroom and the use of the computer. The largest computer room in this category was 600 square feet.

2. *"Large" batch system.* The Mt. Union College facility was the only minicomputer in this class, which would be expected to have requirements greater than the preceding group. The area housing the computer measured about 600 square feet. It was unusually crowded, however, because it also housed the IBM 1620 computer, three keypunches, the manager's office, and some related peripheral equipment. The college had a new building under construction to accommodate the computing facility in less cramped quarters, so the crowding was acknowledged to be temporary.

3. *Time-shared systems.* The five colleges with time-shared systems housed their computers in modest space, with user work stations (terminals) located in other areas. The main computer room

area ranged from 64 square feet to 200 square feet, with 150 square feet a reasonable area to simply house the computer system. (The time-sharing computer systems tended to be physically larger than the other minicomputers since all had disk drives or drums, and most had communications devices and additional memory units as well.) Terminal area requirements were difficult to assess, since many terminals were located in laboratories, hallways, libraries, and other locations with multiple functions. Two colleges placed several terminals in general time-sharing users' areas of about 150 square feet, fairly near the main computer room. Several others had portable terminals which could be wheeled into offices or classrooms.

Initial Training: Nine of the ten colleges designated a faculty member to assume control of the minicomputer installation as a part-time assignment. (The remaining college, Mt. Union, already had a computing facilities staff which assumed the minicomputer facility as part of its existing operation.) Most colleges, initially, released 25% of the faculty member's time for this purpose. Since there was commonly no prior experience with computer operating systems, compilers, hardware operations, etc., start-up training of the faculty member was a necessary consideration. In every case, the vendor provided some form of instruction, ranging from on-site check-out sessions, to classes held in metropolitan areas, to formal courses offered at regional training centers. Digital Equipment Corporation was cited by two of the colleges as providing an excellent series of training courses in Maynard, Massachusetts. Most minicomputers were scheduled for a fall delivery so that the summer of 1970 was used as a training period in many cases.

Maintenance: Vendors generally included a free maintenance period for the initial 90 days of operation. Beyond this, however, the colleges had several options. Since the equipment was purchased, it was possible to have no contracted maintenance agreement at all. Four colleges elected this route. Repairs were available on call or by shipment of defective components by mail. At three of these colleges, essentially no maintenance was required on the minicomputer system throughout the total three years of the experiment, with the occasional exception of mechanical components such as tape or card readers, or teletype terminals. The remaining colleges initially contracted for maintenance on the computer vendor's equipment, leaving teletype repairs to be covered locally. Since maintenance contracts commonly cost $4,000 to $5,000 annually, colleges that gambled with on-call service tended to have considerable savings. It happened that the only college to experience a need for significant repair service did not contract for maintenance, yet still had costs totaling less than the vendor's maintenance agreement price.

Software: The minicomputers in the experiment were geared to primary use with the BASIC language. With this language, all the systems were operational very shortly after delivery. The colleges had plans for languages other than BASIC, however. In this respect, variability of success was noted. As a generalization, one could easily observe that the older the design of the minicomputer, the more readily the additional software options functioned. Users of the PDP-8, which had the longest lineage, had little problem mounting a variety of capabilities derived either from the vendor or other PDP-8 users. Advice was also readily available from the other users. With newer equipment, it was a different story. The University of the South, with their Data General Nova representing one of the newest designs, struggled to install FORTRAN for 26 months before it became operational. Smaller memories generally produced software hardships. The colleges with less than 12,000 words of memory experienced difficulty implementing FORTRAN.

By the end of 18 months a wide array of languages was supported. In addition to BASIC, nine of the ten colleges had FORTRAN, six offered ALGOL, the DEC PDP-8's and PDP-11 colleges had FOCAL, three had editing capabilities, and one offered COBOL. Nine colleges also used an Assembler Language for instruction.

Service Hours, Charges, and Costs: Four colleges maintained hours of availability during the daytime only, commonly 8 a.m. to 5 p.m. Four others were open until late evening. The remaining two colleges permitted computing any time. Nine colleges had no charges for use of the computer, although one of these charged a modest lab fee. MacMurray College, which was leasing service to other colleges, charged $250 per month for an off-campus terminal service.

Statistics maintained during the first two years on the total costs of the minicomputer operations, including prorated fractions of all salaries, wages, benefits, indirect costs, and travel (not commonly costed as expense items in previous evaluations), as well as equipment and materials expenses, showed an annual cost per registered student averaging under $16.50 among the ten colleges.

Some Start-up Problems: A wide variety of incidents and minor problems occurred. Some of the more interesting were:

- Difficulty uncrating the teletype.
- A computer room ceiling had been spray painted before equipment was installed. Aparently some spray mist turned to a sort of dust and dropped on equipment causing problems.
- Vendor documentation (noted particulary with Data General equipment) had shortcomings.
- Paper tape readers reacted differently with different tape supplier's paper. The DEC paper tape reader wouldn't read tapes prepared on teletypes.

- The ASR-33 model teletype was found to be designed for too light duty by three colleges. Preference now is for ASR-35 or NCR terminals instead.
- Initial problems at three colleges with Optical Mark Reader was a common hardware complaint.
- Hewlett-Packard maintenance service charges were much higher than earlier quotations.
- Digital Equipment Corporation shipped software on paper tapes with BASIC using one format, FORTRAN using another, and the time-sharing system still another.
- Considerably more than half-time effort was needed by the person in charge, initially.

Section V

The On-Campus Minicomputer: Its Effects, Changes from Initial Plans, Problems, and Second Thoughts

By the second year of the experiment, virtually all early problems, learning processes, and operations settled down. The institutions began to identify some priorities among a number of objectives, and to rectify minor elements of mistaken planning. This section describes a number of experiences, problems, and judgments which occurred during the "mature" phase of the experiment.

Instructional Use: Most of the colleges experienced a dramatic increase in (1) numbers of students using computers, (2) numbers of departments introducing computer usage into courses, and (3) numbers of courses specifically dedicated to computer instruction. At Canisius College, the largest institution, the pre-minicomputer usage (spring 1970 semester) reflected use by about 100 students per term, and by four departments' courses. By 1972, the number of student users had increased to more than 1,000 during the fall semester, distributed among 19 departments. Mt. Union College established four new courses in computer programming. MacMurray College, with a large time-sharing system, extended its service by installing terminals in two other local colleges, which averaged 9 to 10 connect hours each per day. Additional terminals were added in new areas, bringing the number to eight installed at various sites on the MacMurray campus.

Computer access was cited by faculty at several institutions as the primary instructional advantage of an on-campus minicomputer. At MacMurray around-the-clock availability of reliable service via eight terminals had replaced half-time use of one terminal. Courses could depend on the accessibility of a computer to assist with lab courses, or to solve complex homework assignments, so courses were redesigned in chemistry and physics. At most colleges, the pattern of instructional growth showed an introduction of two to four computing courses, plus a number of new computer-related courses developed in other disciplines.

Numbers of students using the computer increased by a factor of nearly 10, with a mean number of 20 to 30 students using computers on a campus prior to the experiment increasing to a mean of about 200 students.

Equipment Upgrading: The increased use, plus desires for more advanced features, resulted in a number of changes from the original equipment installed. Four colleges increased the number of terminals attached to the minicomputer (of the six minicomputers whose operating systems/hardware would permit an expanded number of terminals). Memories and other storage capabilities were increased.

The HP2114 computers at Maryville and Illinois Benedictine unfortunately did not have memory expansion capability; however, of the remaining eight colleges, four increased the sizes of their memories. Five colleges increased on-line storage capability by adding additional disk, drum, or magnetic tape capacity. Two colleges added plotters, and one added a line printer. An interesting improvement at MacMurray was a higher speed terminal utilizing a Diablo printer mechanism using an interface designed and built at the college. At Hollins College various remote laboratory apparatus, such as spectrometers and scopes, were successfully connected on-line using a flexible plugboard arrangement developed by the Hollins students and staff.

The level of computer expertise exhibited a remarkable transformation over a three-year period. An initial pre-experiment meeting, held in 1970, was attended by a group of ten generally inexperienced neophytes. By the second year, the same group's meetings disclosed interchanges of systems programming hints, new circuit designs and modifications, money-saving equipment repair ideas, and dozens of solutions to problems considered upapproachable in 1970.

Problems: Problem areas ranged from a few common to most colleges, to some (sometimes curious) happenstances unique to one institution. A common complaint was the lack of sufficient time for the lead individual to spend with his computing responsibilities. A number of colleges had allocated only one-fourth or one-third time to this important function. A concensus indicated a minimum of one-half time is needed to satisfactorily head the operation of a minicomputer system.

Vendor failure to satisfactorily maintain equipment was experienced on occasion, though rarely. Vendor software problems were somewhat more common, with the most satisfactory record achieved by colleges with PDP-8 or Hewlett-Packard equipment. Most systems settled down within the first six months and performed well from then on. The notable exception was the Data General Supernova at Canisius College, which experienced major component failures throughout the experiment. A series of 46 equipment failures resulted in such things as replacement of disk drives on three occasions, numerous shipments or replacement and damaged units, three instances of returning the entire computer to the vendor's factory for repairs, and two intervals of prolonged periods (more than a month) without a computer. It should be emphasized that Canisius had an early production version of the newly-designed Supernova.

Software problems seemed to be related to the newness of computer design. Erskine College, although able to offer BASIC service to four terminals on their PDP-11/20, was unable to implement the features originally planned to operate under RSTS-11. The memory

was an absolute constraint, resulting in a vendor contribution of an additional 8,000 words of memory. Unfortunately, the additional memory board was supplied without an appropriate interface, and during the first three years was not usable. (The vendor responded with some technical assistance and additional hardware after the experiment ended.) The failure of the FORTRAN compiler on the University of the South Nova computer was a topic at three consecutive semi-annual meetings. This problem was finally resolved with some assistance from another Nova installation.

Hardware troubles were most often associated with mechanical peripheral components. The most common failure was with the optical mark card readers. At Illinois Benedictine the card reader was the only component to fail during the first two years. At Mt. Union College, the heavy batch workload proved too much for the light duty optical card reader, and a replacement Documation reader was installed. Disk or drum drives provided many early problems at Canisius and MacMurray, and a disk head crash represented one of the rare system problems at Mt. Union. Card and paper tape readers were found to have idiosyncracies related to type of paper stock, colors of ink used, and other seemingly innocent variables. Experience seemed to clear up most problems. The minicomputers themselves, with the notable exception at Canisius, were solid performers throughout.

Afterthoughts: The colleges were prompted from time to time about what would be done differently "if I had it to do over." Responses were in three categories. Some common afterthoughts were:

1. *Planning* (including hardware selection)
   a. Would have more terminals.
   b. Would not get teletypes from the manufacturer, but from an independent (less costly) source.
   c. Would not use the optical card reader.
   d. Would plan more core. (Some also indicated a preference for 16-bit over 12-bit memory.)
2. *Installation*
   a. Would have room and storage cabinets prepared before delivery of machine, with better security.
   b. Would shop around for paper and tape.
   c. Would have more space.
   d. Would attend vendor's schools earlier.
   e. Would train a technician for some maintenance.
3. *Operations*
   a. Would allocate more time to operate the center; minimum of half-time. (This was a response from seven of the colleges.)
   b. Would make more use of student assistants.

Section VI

Some Conclusions and Suggestions; Common Questions Answered; Table I: Summary of Minicomputer Equipment and Costs

This section brings together some of the major findings of the experiment, with an aim to assist other institutions considering a minicomputer for instructional use. A basic conclusion, expressed unanimously by the ten somewhat varied types of undergraduate institutions, is that a minicomputer system is the best buy source of computing power for most instructional activities. The combination of low cost, constant availability, control, and the many advantages of an on-campus facility make the minicomputer a preferred choice over known off-campus alternatives.

Many conclusions have a financial basis. Cost statistics and equipment configurations are summarized at the end of this section in Table I. This table shows the minicomputer system purchased by each institution, its purchase price (in 1970, for most equipment), and average annual costs. The average annual costs are broken down as "equipment," "salaries and benefits," and "other" components, and include calculation of annual costs per enrolled student. The latter figure corresponds with a "rule of thumb" statistic calculated in a number of previous experiments and projects, some of which were noted in the Introduction. It is useful as a rough guide; in this instance, it must be noted that the annual costs per student include all costs, not simply equipment costs. The figure ranges from $5.40 to $33.24 per student per year, of which equipment costs (often the sole basis for calculating cost per student in other experiments) range from $2.80 to $17.10 per student per year. In all, it may be noted that 12,450 full-time students were enrolled collectively by the ten institutions, with a mean total annual cost per student of $17.52. (Of that total, $9.30 is the mean annual cost per student for equipment.) The institutions which had prior experience using one or two interactive terminals to a remote time-sharing computer, felt the minicomputer source was unquestionably superior. In addition to cost savings (institutions here, and in previous NSF experiments had experienced average annual costs of about $19 per student), greater availability, and other obvious advantages cited above, there was an expressed academic advantage. This is hard to quantify, but includes the advantage of having a facility on which software changes, operating system experiments, and other developmental activities can take place which would not be possible on a large or non-institutional facility. In addition, the on-site system created an atmosphere or center of activity supportive of creative thinking about computing.

Prior to the experiment, the colleges established rough budget guidelines for the various levels of minicomputer systems. The

mean estimated total annual cost was $28,130. The actual mean total annual cost turned out to be $21,810. The average annual cost per student was estimated in advance to be $21.42, which compared to an actual cost of $17.52. Thus it was observed that costs were actually somewhat lower over three years than projected.

Equipment costs were found to average 53% of the total expenses. This component of the costs ranged from $4,700 to $22,000 per year with a mean of $11,580. It would be expected that costs for comparable systems would be somewhat below these figures today, although one must not hastily apply a factor of, say, 50% (which may accurately reflect the comparable price of a processor unit today versus 1970) too broadly. Processors and memories have come down in cost drastically. However, most mechanical devices (such as disk drives, tape drives, card readers) have experienced less reduction. Maintenance costs, included here as equipment expense, have increased. Overall, the minicomputer system of today should probably cost about 80% of the comparable 1970 version.

Other costs, however, have increased. Salaries, benefits, publications, and travel expenses generally total about 25% more than in 1970. Supply costs are 100% higher for paper items than just two years ago. Since salaries and benefits constitute 27% of total annual costs, and "other" costs (largely supplies and institutional overhead) represent the remaining 20%, the end result of a new 1974-75 operation should have a price tag close to par with 1970 costs.

The institutions were queried, after the fact, about typical questions, which might be asked by prospective institutional minicomputer users, and what the answers to those questions should be. The following are some typical questions, with responses, which could be asked by institutions exploring minicomputers.

What is the most common oversight when planning a college minicomputer operation?

Underestimating the amount of time needed by the person (faculty member) responsible for the operation, especially during the first year. A minimum of 50% of full-time should be allocated, with more time available during the first year, if possible.

What is the primary equipment difference that most colleges would opt for if they could redesign the system after several years experience?

The most common change would be a computer with a larger memory. (Eight of the ten institutions gave this response.)

What vendor would you choose if you were to "do it over?"

Curiously, the response to this question, in 1973, was a preference

for the *same* vendor as previously used. Some qualifications were attached, indicating that perfect satisfaction was not always present. Most consistent support for *equipment and reliability* was present from Hewlett-Packard users. The support on behalf of *software* offered was mixed, supporting Hewlett-Packard most favorably for operating systems software, and Digital Equipment for applications. *Maintenance service* was most often criticized by users of Hewlett-Packard equipment. Oddly, although each institution expressed favoritism for the vendor it used during the 1970-73 experiment, the only institution to actually replace its initial minicomputer with a completely new system (University of the South) changed from Data General to a Hewlett-Packard system. It should be noted that this institution upgraded from a small initial system to a very large new system which had major administrative requirements in addition to an order of magnitude expansion of instructional capabilities. More recent comments (late 1974) indicate some consideration would be given to newer vendors, such as Prime or Interdata. Used equipment is also available at very attractive prices, as is plug-compatible equipment, so that combinations of used components and primary-vendor plus secondary-vendor peripherals or memories would now be explored.

How many students may be adequately supported by one interactive BASIC terminal?

(Answered by the five institutions with interactive minicomputers.) Two institutions responded with 22 to 25, with three institutions answering 10 to 15. The variability reflected the amount of computing required of the "typical" courses. The same question has been addressed by other institutions with interactive experience. A consensus indicates 22 to 25 students per terminal to be a maximum number in a course with modest assignments. More institutions prefer a terminal to serve no more than 15 students in a computing course.

Is there a high risk of equipment failure with a minicomputer? Is a maintenance contract a necessity?

Component failure in equipment other than teletypes, card readers, disk drives, and tape drives was almost non-existent. Following an initial shake-down period (three to six months), every institution that shifted to "on call" service, in place of a monthly contract, reduced its maintenance costs. In most cases, the reduction was more than 80%. The consensus favored maintenance contracts only for mechanical components (if at all) with maintenance of teletypes separate from vendor-supplied service contracts in any event.

Was there any indicator that would tend to identify in advance whether an institution would have a successful minicomputer operation?

All institutions achieved successful operations, within a variety of objectives. The *quickest* achievement of a satisfactory smooth operation (which would probably also tend to maximize successful instructional use) occurred at institutions where (1) prior faculty/staff experience with computing existed in some numbers (10% to 20% of faculty) prior to arrival of the minicomputer, and (2) ample time was provided to allow one person at least half his time to develop the facility.

What are recommended steps in computer selection to assure a reasonable choice of equipment?

If satisfactory computing service is a primary objective, don't be a pioneer. One institution's hints were: (a) buy from an established vendor. (b) Select a time-tested mainframe and peripherals. (Personal visits and calls on customers with the same equipment are strongly advised.) (c) Stipulate in the contract that all hardware and *software* must be in full operation on-site before any payment is made.

Another institution suggested asking vendors for sample systems to run experimentally for a test period. Still another suggested that primary attention should be paid to the availability of time-tested software in the areas of most interest.

Table I— Equipment and Costs Summary

Institution	Minicomputer		Average Annual Costs				
	Configuration	Cost	Equipment*	Salaries & Benefits	Other**	Total	Annual Cost per Enrolled Student
Benedict College (1,300 students)	PDP8/I-D 12,000 words core 256K disk 4-ASR 33 High-speed tape rdr.	$57,000	$12,700	$4,400	$5,000	$22,000	$17.00
Canisius College (3,500 students)	Supernova 24,000 words core 256K disk 6-ASR 33 Sykes Cassette	$47,500	$9,800	$4,900	$4,200	$18,900	$5.40
Delaware State College (1,000 students)	PDP8/I 4,000 words core 32K disk 1-ASR 33 Optical Card Rdr	$20,700	$4,700	$8,000	$5,400	$18,100	$18.10

Table I— Equipment and Costs Summary (Continued)

Institution	Minicomputer		Average Annual Costs				
	Configuration	Cost	Equipment*	Salaries & Benefits	Other**	Total	Annual Cost per Enrolled Student
Erskine College (700 students)	PDP 11/20 16,000 words core 256K disk 4-ASR 33 2-DEC tape drives High-speed tape rdr	$56,000	$12,000	$3,600	$2,000	$17,600	$25.14
Hollins College (1,050 students)	PDP8/I-D 16,000 words core 7-ASR 33 2-DEC tape drives High-speed tape rdr Lab Interface DEC AX08 Heath EU-801	$89,000	$17,800	$10,400	$6,700	$34,900	$33.24

Table I— Equipment and Costs Summary (Continued)

Institution	Minicomputer		Average Annual Costs				
	Configuration	Cost	Equipment*	Salaries & Benefits	Other**	Total	Annual Cost per Enrolled Student
Illinois Benedictine College (1,000 students)	HP 2114 8,000 words core 1200K disk 2-ASR 35 Optical Card Rdr. High-speed tape rdr.	$26,000	$7,000	$7,500	$6,300	$20,800	$20.80
MacMurray College (1,000 students)	HP 2116B 16,000 words core 984K Drum IBM-compatible tape 11-ASR 33	$94,500	$22,000	$5,500	$3,500	$31,000	$31.00

Table I— Equipment and Costs Summary (Continued)

Institution	Minicomputer		Average Annual Costs				
	Configuration	Cost	Equipment*	Salaries & Benefits	Other**	Total	Annual Cost per Enrolled Student
Maryville College (700 students)	HP 2114B 8,000 words core 2-Tennecomp tape cassette drives 1-ASR 33 1-NCR terminal Optical Card Rdr. X-Y Plotter High-speed tape rdr.	$29,500	$5,700	$3,700	$2,800	$12,200	$17.43
Mt. Union College (1,200 students)	HP 2116B 16,000 words core 1,240K disk 1-ASR 33 Optical Card Rdr. 600 CPM Card Rdr. 300 LPM Printer High-speed tape rdr.	$93,000	$18,400	$9,700	$5,500	$33,600	$28.00

Table I— Equipment and Costs Summary (Continued)

Institution	Minicomputer		Average Annual Costs				
	Configuration	Cost	Equipment*	Salaries & Benefits	Other**	Total	Annual Cost per Enrolled Student
University of the South (1,000 students)	Nova 12,000 words core Optical Card Rdr. 1-ASR 33 High-speed tape rdr.	$24,000	$5,700	$1,600	$1,600	$8,900	$8.90
Totals (12,450 students)		$537,200	$115,800	$59,300	$43,000	$218,100	$17.52
Average (1,245 students)		$53,720	$11,580	$5,930	$4,300	$21,810	$17.52

Legend:
*Five-year linear depreciation (after discounts, where applicable), plus maintenance costs.
**Includes indirect costs, materials, publications, and travel.